7th Asia-Pacific Conference on Plasma Physics, 12-17 Nov, 2023 at Port Messe Nagoya

Gyrokinetic simulation of chaotic cross-field electron transport in high wavenumber shear Alfven wave fields and comparison with experiments

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In the shear Alfven wave (SAW) spectrum, high perpendicular wavenumbers are associated with large parallel wave electric fields. To create waves of this type in an experiment, a specialized antenna ("Alfvén tennis racket") was constructed and implemented in the Large Plasma Device (LAPD) at UCLA [1]. One of the main objectives of this study is to investigate chaotic cross-field electron transport using a localized electron beam source in the presence of the high perpendicular wave number SAW electric and magnetic fields. An example of the measured magnetic field of the wave is shown in Figure 1. The measurement plane was 4.88m from the antenna and a background magnetic field strength of B_{oz}=500G was present.

In order to model the cross-field electron transport, a gyrokinetic particle-in-cell (PIC) model is used which follows the gyro-averaged drift equations of motion for ions and drift-kinetic electron dynamics. Electron-ion collisions and realistic LAPD plasma parameters, such as ion-to-electron mass ratio (Helium), are used. The SAW wave fields in the model are initialized using wave magnetic fields taken directly from experiment with spatial pattern that are consistent with the "tennis racket" antenna.

A low energy electron beam (~5 times the electron thermal speed) is initialized at various axial locations from the antenna in order to test collisionless and collisional effects on cross-field electron beam dynamics. Another main parameter in the model is the strength of the antenna wavefields and their influence on the cross-field chaotic scattering. Particle tracking of the tagged electron beam particles in the simulation allow for the determination of chaotic dynamics parameters such as the Lyapanov exponent and cross-field diffusion coefficient which can then be compared with experiment.

References

[1] W. Gekelman et al., Rev. Sci. Instrum., 90,83505 (2019)

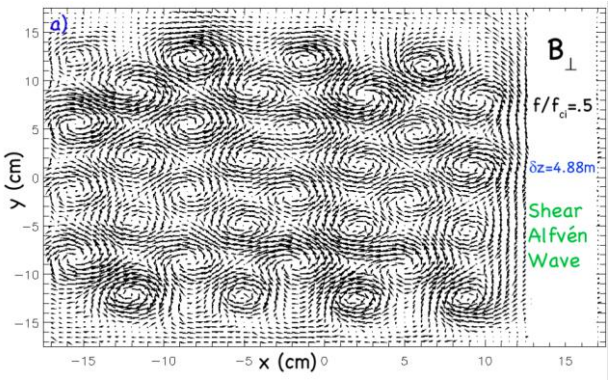

Figure 1 Measured magnetic field of a shear Alfvén wave at half the cyclotron frequency. Here $\lambda_{\perp}$=7cm and $l_{\parallel}$=4.8m